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- Polymer Materials Science -

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Scope of Research

The structure and molecular motion of polymer substances are studied using mainly scattering methods such as neutron, X-ray and light with intention of solving fundamentally important problems in polymer science. The main projects are: the mechanism of structural development in crystalline polymers from the glassy or molten state to spherulites; the dynamics in disordered polymer materials including low-energy excitation or excess heat capacity at low temperatures, glass transition and local segmental motions; formation processes and structure of polymer gels; the structue and molecular motion of polyelectrolyte solutions; the structure of polymer liquid crystals.

Research Activities (Year 2003)

Presentations

Electrolyte and Non-electrolyte Behavioral Boundary in Polyelectrolyte Solutions, Nishida K, Kaji K, Kanaya T, The 2nd NIST-KIPS Symposium on Polymer Science, Gaithersburg, USA, 21 March.

Structure and Dynamics of Polymer Networks As Revealed by Scattering Techniques, Takahashi N, Kanaya T, Nishida K, Kaji K, 9th International Seminar on Elastomers, Kyoto, 2 April.

Inelastic Neutron Scattering Studied on Ultra Thin Polymer Film, Inoue R, Yamano H, Nishida K, Kanaya T, Tsukushi I, Shibata K, Autumn Meeting, The Physical Society of Japan, Okayama, 22 September.

Mesomorphic Phase Formation and Crsytallization of Polypropylene, Konishi T, Nishida K, Kanaya T, Kaji K, Autumn Meeting, Society of Polymer Science, Japan, Yamaguchi, 24 September.

Crystallization of Isotactic Polypropylene under Shear Flow - Effect of Shear Rate and Strain -, Ogino Y, Takahashi N, Matsuba G, Sharma L, Nishida K, Kanaya T, Kaji K, Autumn Meeting, Society of Polymer Science, Japan, Yamaguchi, 24 September.

The Effect of Phase Separation on Crystal Nucleation for Polyolefin Blends, Matuba G, Shimizu K, Wang H, Wang Z, Han C C, Autumn Meeting, Society of Polymer Science, Japan, Yamaguchi, 25 September.

Polymer Crystallization Under Shear Flow, Kanaya T, European Discussion Meeting on Polymer Physics, Waldau, Germany, 26 September.

Grants

Nishida K, Control of higher order structures of polymer materials by a rapid temperature jump method, Industrial Technology Research Grant Program by New Energy and Industrial Technology Development Organization (NEDO) of Japan, 1 April 2001 - 31 March 2004.

Kanaya T, Sharma L, Production of an artificial bone material based on a hydroxyapatite polymer base, involving polyurethane hybrids, Grant-in-Aid for Scientific Research (JSPS Fellows), 15 April 2002 - 15 April 2004.

Kanaya T, Nishida K, Polymer Crystallization under Shear Flow - Aiming to Reveal the Formation Mechanism of Fiber Structure, Grant-in-Aid for Scientific Research (B) (2), 1 April 2003 - 31 March 2005.

Kanaya T, Tasaki S, Dynamics of Graft Polymer Chains in Nanometer Scale by Neutron Spin Echo, Grant-in-Aid for Exploratory Research, 1 April 2003 - 31 March 2005.

Inelastic Neutron Scattering on Polymer Thin Films

Properties of polymer thin films and/or polymer surfaces are very different from those of the bulk and related to many phenomena such as adhesion, wetting, surface friction, and hence are important from viewpoints of not only science but also industrial applications. Aiming to elucidate the special nature of thin films and/or surfaces, we have investigated the thermal expansion behavior of polystyrene (PS) thin films using X-ray reflectivity (XR) as well as dynamics of PS thin films using an inelastic neutron scattering technique. One of the most interesting findings in this study is reduction of thermal expansivity in the glassy state with deceasing the film thickness. Onset thickness of the reduction is very close to twice of the radius of gyration of a polymer chain, suggesting that it is originated from the confinement effects of a polymer chain. In order to elucidate the origin of the reduction of the expansivity, we performed inelastic neutron scattering measurements on PS thin films 100 and 40 nm thick below the glass transition temperature T_g (=373 K). The observed dynamic scattering laws $S(Q,\omega)$ are shown in Figure 1. Analyzing the spectra, we found that the mean square displacement $\langle u^2 \rangle$ decreases with the film thickness, suggesting the reduction of the expasivity is caused by stress-induced hardening of polymer chains.

Novel Crystal Morphology Generated by Crystallization from Meta-stable State

When polymers in bulk are crystallized quiescently by thermal processing, crystal aggregates of spherical silhouette are usually formed, which are well known as "spherulite". So it is rare case that polymer crystal has special morphology other than spherulite. Although, isotactic polypropylene (iPP) has been known as a typical polymer forming spherulite (Figure 2(a)), we have succeeded in generating novel iPP crystals having "bamboo leaf-like (BL) morphology (Figure 2(b)) by a rapid temperature jump technique.

When the molten iPP is rapidly quenched with a rate faster than 80 °C / sec, it solidifies in a meta-stable state, the so-called mesomorphic phase. It is said that the structure of the mesomorphic phase is liquid crystal like, but the details of it are still in discussion. When the mesomorphic iPP was heated up to a certain temperature near melting temperature, the BL crystals were found. The BL crystals grew until the good part of matrix was run out and micro~meso voids were left. The BL crystals showed higher crystallinity than the ordinary spherulites. Thus, the polymer crystallization passing through a meta-stable state has a potential to control higher order structure of polymer materials.

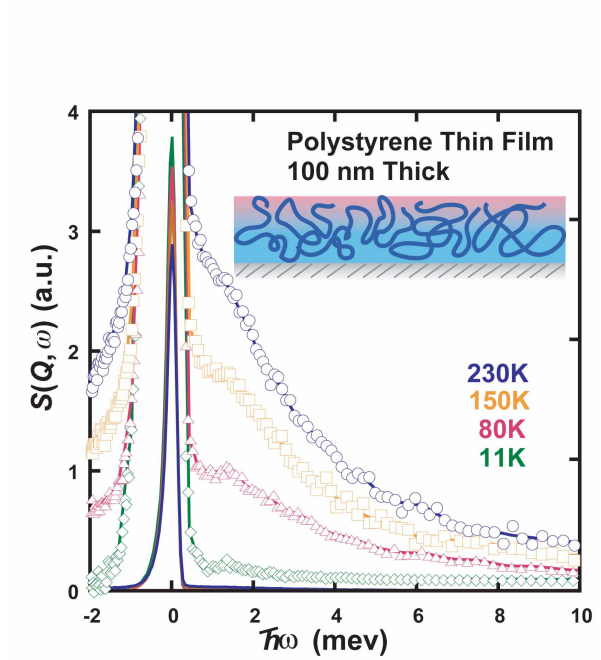

Fig. 1 Schematic sketch of polymer thin film and the dynamic scattering law S(Q,ω) of polystyrene thin film 100 nm thick.

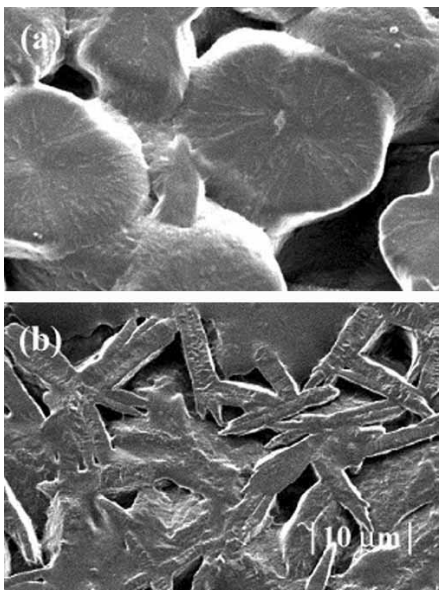

Fig. 2 Scanning electron microscope (SEM) images of iPP crystals. (a): ordinary spherulites. (b): typical BL crystals.